

PROVENANCE DATES AND FELDSPAR FRACTIONATION IN LATE WISCONSIN TILL OF THE CUBA MORaine, OHIO¹

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ABSTRACT. Late Wisconsin till of the Cuba Moraine in Ohio consists of sediment contributed by local Paleozoic bedrock and by the igneous and metamorphic rocks of the Canadian Precambrian Shield. Feldspar in this till is derived predominantly from the Grenville and Superior structural provinces of Canada which are 1.07 b.y. and 2.70 b.y. old, respectively. Rb-Sr provenance dates of feldspar in the -18 +35 mesh fractions of till range from 1.21 b.y. to 2.01 b.y. and confirm that the feldspar is a mixture of grains from these 2 provinces. The K-feldspar/plagioclase ratio of the -18 +35 mesh fraction is consistently greater than that of the -120 +250 mesh fraction. This relationship also was seen in the till of the Powell Moraine of Ohio and in Cenozoic till of Antarctica and may be caused by preferential grinding of plagioclase during transport at the base of the ice. The feldspar in the -18 +35 mesh fraction is enriched in K-feldspar by about 25% compared to feldspar in the -120 +250 mesh fraction of till in the Cuba Moraine.

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INTRODUCTION

The Cuba Moraine of Ohio is one of many glacial deposits in the midwestern United States and Canada that were deposited during the Late Wisconsin Glaciation. The till of the Cuba Moraine is composed of detritus originating from the Paleozoic sedimentary rocks that form the bedrock of this region and from the igneous and metamorphic rocks of the Canadian Precambrian Shield. Feldspar is a common constituent of Ohio till and is derived almost entirely from the Precambrian Shield of Canada (Gross and Moran 1972, Taylor and Faure 1979, 1981). This feldspar is a mixture of grains derived from the Grenville and Superior structural provinces of the Canadian Shield that recrystallized 1.07 b.y. and 2.70 b.y. ago, respectively. Rb-Sr dates of the feldspar, separated from the till of the Powell-Union City Moraine, range from about 1.2 to 1.9 b.y. and thus confirm that the feldspar has a mixed provenance (Taylor and Faure 1981).

Taylor and Faure (1981) analyzed feldspar in 4 size fractions of 2 till samples from the Powell Moraine and showed that the K-feldspar/plagioclase and Rb/Sr ratios increase with increasing grain size. A similar relationship also was observed in the Cenozoic tills of the Transantarctic Mountains by Faure and Taylor (1981a). The objectives of the present study are to determine the Rb-Sr provenance dates of feldspar in till from the Cuba Moraine and to study the apparent mineralogical fractionation of feldspar first observed by Taylor and Faure (1981).

STUDY SITE

The samples for this study were collected along the strike of the Cuba Moraine between Xenia and Chillicothe in south-central Ohio (fig. 1). This moraine, studied in some detail by Foster (1950) and Rosengreen (1970), is shown on the glacial map of Ohio (Goldthwait et al. 1961), and is discussed by Dreimanis and Goldthwait (1973) in a general history of the Wisconsin Glaciation in the Huron, Erie, and Ontario lobes. Two ¹⁴C age determinations from Todd Creek valley west of

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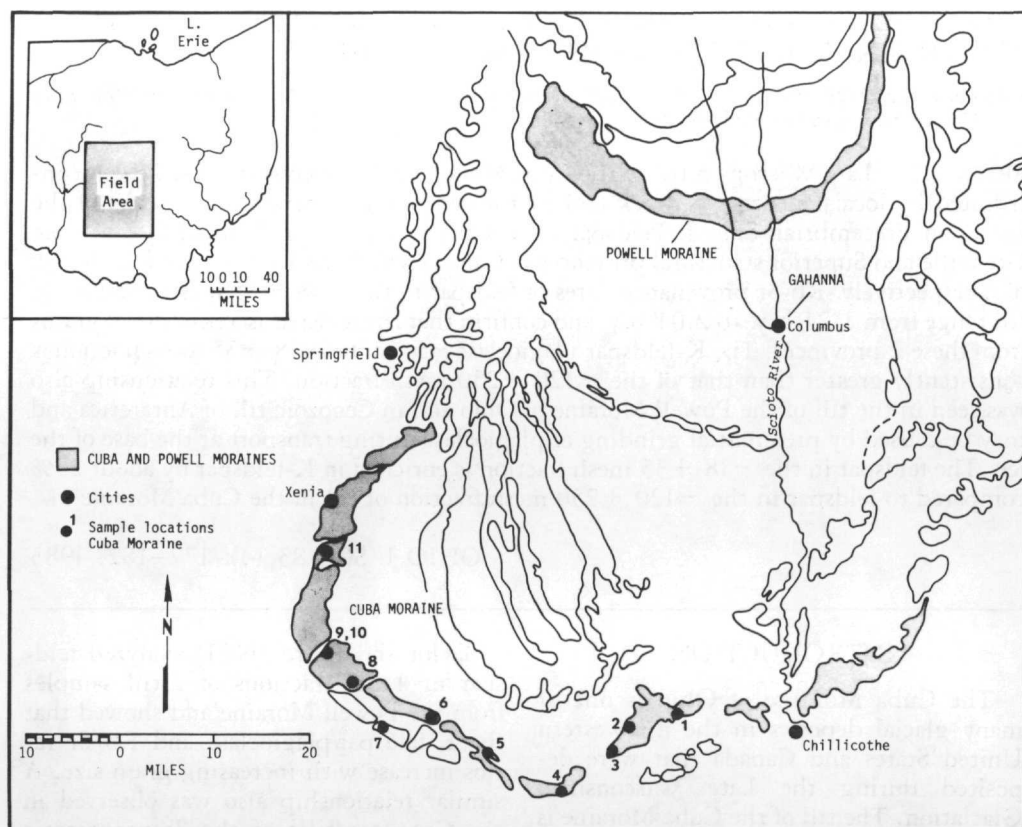


FIGURE 1. Map showing Cuba Moraine, Powell Moraine and the Gahanna till location in central Ohio. The collecting sites along the Cuba Moraine are identified by number in table 1.

Sligo, Ohio, are $21,137 \pm 1,435$ years B.P. (OWU-159) and $22,255 \pm 1,652$ years B.P. (OWU-160). Wood from the Cuba Moraine 1.6 km northwest of New Petersburg gave a ^{14}C date of $20,460 \pm 700$ years B.P. (W2459). Rosengreen (1970) concluded from these dates that the Scioto sublobe of the Erie lobe reached its maximum southward advance about 21,350 years B.P.

FELDSPAR PROVENANCE DATES

In an earlier study, Taylor and Faure (1981) extracted feldspar from the $-60 + 120$ U. S. standard mesh fraction because it contains about 32% of the feldspar in Late Wisconsin till in Ohio (Taylor and Faure 1979). For the current study, the $-18 + 35$ mesh fraction was analyzed because it has a higher Rb/Sr ratio and is

therefore a more sensitive geochronometer. Feldspar in this fraction also tends to be less weathered than the $-60 + 120$ mesh fraction because it has less surface area per unit weight. Carbonate grains were dissolved by leaching with 2N HNO_3 and the magnetically susceptible mineral grains were removed by means of a Frantz Isodynamic Magnetic Separator. The samples were further refined by ultrasonic treatment. Rb/Sr ratios were determined by X-ray fluorescence and $^{87}\text{Sr}/^{86}\text{Sr}$ ratios were measured on a mass spectrometer (Nuclide Corp., Model 6-60-S) as described by Taylor and Faure (1979). The Eimer and Amend SrCO_3 interlaboratory isotope standard was analyzed 2 times in the course of this study and has an average $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of 0.70811 ± 0.00015 .

($1\bar{\sigma}$). This result is in agreement with values reported from other laboratories. Rb-Sr provenance dates were calculated using a value of 0.7040 for the initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratio and $1.42 \times 10^{-11}\text{y}^{-1}$ for the decay constant of ^{87}Rb .

The resulting dates (table 1) range from 1.21 to 2.01 b.y. and have an average of 1.61 ± 0.07 b.y. ($1\bar{\sigma}$). The date for the sample collected at Kingman (table 1) was omitted from the average because it contained residual grains of dolomite as discussed later in this report. All of the provenance dates are between the ages of the Grenville Province (1.07 b.y.) and the Superior Province (2.70 b.y.) of Canada and therefore indicate the feldspar grains are mixtures from these 2 source areas. This result compares favorably to dates from that part of the Powell Moraine which was also deposited by the Scioto sublobe of the Erie lobe (fig. 1). The dates from this section of the Powell Moraine range from 1.2 b.y. to 1.8 b.y. with a mean of 1.54 ± 0.06 b.y. (Taylor and Faure 1981). The similarity of provenance dates for these 2 segments of the recessional moraines suggests the feldspar was derived from the same sources and was mixed approximately in the same proportions. These results confirm the conclusion of Dreimanis and Goldthwait (1973) that the till of the Cuba Moraine, like that of the Powell Moraine between Crestline and Rushsylvania,

Ohio, was deposited by the Scioto sublobe during Late Wisconsin time.

A suite of 17 samples from the Brown Till at Gahanna, Ohio, (Goldthwait 1965, Taylor and Faure 1982) has a range of dates from 0.91 b.y. to 1.40 b.y. and a mean of 1.20 ± 0.16 b.y. This till was presumably deposited during an earlier advance of the Scioto sublobe and may be older than the till of the Powell Moraine. The provenance dates of the Brown Till are lower than those from the Cuba and the Powell Moraines. One possible explanation for this result is the presence of feldspar originating from the Berea sandstone (Mississippian) from which more than 30% of the clasts in this till were derived (Taylor and Faure 1982). The till of the Cuba Moraine does not contain sandstone clasts in appreciable concentrations which means the provenance dates of this till depend primarily on the proportion of feldspar grains derived from the Grenville and Superior Provinces of Canada.

FELDSPAR FRACTIONATION

Taylor and Faure (1981) reported that the Rb/Sr ratios of feldspar in 4 size fractions of till collected at Buck Run and Greenville, Ohio, along the Powell Moraine increase with increasing grain size. They found a similar correlation between K-feldspar/plagioclase ratios and grain size. The reason for this relationship is that

TABLE 1
Rb/Sr, $^{87}\text{Rb}/^{86}\text{Sr}$, 87/86 ratios and dates for feldspar concentrates in till, Cuba Moraine, Ohio.

Sample	Rb/Sr	$^{87}\text{Rb}/^{86}\text{Sr}$	87/86	Date, b. y.
1. Lattaville	0.1761	0.5102	0.71546	1.56 ± 0.07
2. S. Salem	0.2201	0.6379	0.71889	1.62 ± 0.08
3. Fruitdale	0.1480	0.4288	0.71639	2.01 ± 0.20
4. Rainsboro	0.2749	0.79668	0.71894	1.31 ± 0.04
5. Samantha	0.1801	0.5218	0.71683	1.71 ± 0.06
6. New Vienna	0.2192	0.6351	0.71591	1.31 ± 0.05
7. Martinville	0.1606	0.4653	0.71617	1.82 ± 0.19
8. Cowan Lake	0.1850	0.5360	0.71622	1.59 ± 0.03
9. Todd Crk. Upper	0.1867	0.5409	0.71655	1.62 ± 0.17
10. Todd Crk. Lower	0.2104	0.6097	0.71751	1.54 ± 0.08
11. Kingman	0.1642	0.4756	0.71223	1.21 ± 0.07

Rb^+ replaces K^+ in K-feldspar and Sr^{+2} replaces Ca^{+2} in plagioclase. Therefore, the Rb/Sr ratio of any given sample appears to be dependent on the feldspar mineralogy which is dependent on grain size. Similar results were obtained by Faure and Taylor (1981a) for Cenozoic tills in the Transantarctic Mountains.

Enrichment of plagioclase in fine grained fractions of till was first noted by Dreimanis and Vagners (1971). Susceptibility of plagioclase to preferential grinding was subsequently reported by Haldorsen (1977, 1978) during a study of till in southeastern Norway. The apparent enrichment of the $-18 + 35$ mesh fraction in K-feldspar may be caused by mixing of fine grained plagioclase with coarse grained K-feldspar. This may happen because plagioclase tends to occur in the groundmass of porphyritic igneous rocks, whereas K-feldspar tends to form phenocrysts and porphyroblasts. A second possible reason for the dependence of the K-feldspar/plagioclase ratio on grain size may be the preferential grinding of plagioclase by glacial ice during transport. Chemical weathering of plagioclase does not account for the observed grain size distribution of this mineral because plagioclase weathers more rapidly than K-feldspar (Krauskopf 1979) and should therefore be depleted in the fine sand fraction.

The present study is part of a comprehensive effort to test the hypothesis that feldspar fractionation is related to distance of transport by the ice sheet (Faure and Taylor 1981b). The feldspar-quartz concentrates were ground to -200 mesh and were compressed into 10-g pellets composed of 3 g of powdered sample and 7 g of boric acid as backing. The K-feldspar/plagioclase (K/P) ratios were estimated by X-ray diffraction (XRD) of these pellets using diffraction peaks at $27.5^\circ 2\theta$ (microcline) and $28^\circ 2\theta$ (plagioclase) for Cu X-radiation. The height above the baseline of each diffraction peak was determined by counting for 100 sec. Eight replicate read-

ings were taken of each peak, and the pellet was rotated 90° after each count. The resulting measurements of the K/P ratios have a reproducibility of about $\pm 10\%$, expressed as one standard deviation of the mean (table 2).

Concentrations of Na and K were measured by flame emission spectrometry and Ca was determined by atomic absorption spectrophotometry (to be referred to collectively as AA). The K/P ratios were calculated from the results.

In the calculation of the K/P ratios from the chemical analyses, we assumed all of the Na was contributed by plagioclase. We believe the systematic error introduced by this assumption is insignificant when compared with precision errors of $\pm 10\%$. Both sets of data are shown in table 2 and are plotted in fig. 2. A least-squares regression of the K/P ratios of both coarse and fine fractions, as measured by XRD and AA, indicates a slope of 1.053, an intercept of 0.0059, and a linear correlation of coefficient $r^2 = 0.7883$. The goodness of fit of the K/P ratios, determined by XRD and AA, to a line having a slope of unity and passing through the origin indicates both analytical methods are yielding identical results on the average and no systematic error exists. If the correlation line is forced through the origin, the linear correlation coefficient increases to 0.9750. The improvement of the correlation achieved by this procedure confirms the absence of systematic errors from the 2 data sets. We conclude, therefore, that the K/P values determined by X-ray diffraction are a valid measure of the K-feldspar/plagioclase ratios of the samples.

An anomalously high concentration of Ca and Mg in the coarse fraction of the sample from Kingman (no. 11, table 2) was attributed to the presence of residual grains of dolomite that had survived the acid treatment. This datum point therefore deviated from the pattern formed by the other data sets. However, when the Ca content was reduced by an appropriate amount, the data for this sample became

TABLE 2
K-feldspar/plagioclase ratios for feldspar concentrates of till, Cuba Moraine, Ohio.

Samples	Fraction Mesh	X-ray Diffraction K/P	Atomic Absorption K/P
1. Lattaville	-18 + 35	0.542	0.570
	-120 + 250	0.359	0.451
2. S. Salem	-18 + 35	0.661	0.674
	-120 + 250	0.526	0.510
3. Fruitdale	-18 + 35	0.596	0.427
	-120 + 250	0.420	0.418
4. Rainsboro	-18 + 35	1.072	0.991
	-120 + 250	0.838	0.782
5. Samantha	-18 + 35	0.501	0.533
	-120 + 250	0.546	0.494
6. New Vienna	-18 + 35	0.639	0.606
	-120 + 250	0.479	0.487
7. Martinsville	-18 + 35	0.866	0.521
	-120 + 250	0.683	0.503
8. Cowan Lake	-18 + 35	0.517	0.497
	-120 + 250	0.372	0.426
9. Todd Crk. Upper	-18 + 35	0.712	0.647
	-120 + 250	0.389	0.465
10. Todd Crk. Lower	-18 + 35	0.637	0.573
	-120 + 250	0.619	0.513
11. Kingman	-18 + 35	0.434	0.582
	-120 + 250	0.323	0.468

compatible with the others from the Cuba Moraine. The presence of residual dolomite in the -18 + 35 mesh fraction of the sample from Kingman also caused a de-

crease of its $^{87}\text{Sr}/^{86}\text{Sr}$ ratio which resulted in a lowering of the provenance date to 1.21 ± 0.07 b.y. (table 1). This date was therefore omitted from the average of the provenance dates of the Cuba Moraine shown in fig. 3. This incident emphasizes the importance of thorough acid treatment of the coarse fractions of till from western Ohio where dolomite is present in the bedrock.

The average of the K/P ratios of feldspar in the -18 + 35 mesh fractions is significantly greater than that of the -120 + 250 mesh fractions. Based on the XRD data, the K/P ratios are 0.652 ± 0.054 (1σ) for the coarse fraction, whereas the fine fraction has an average K/P value of 0.521 ± 0.045 (1σ). A comparison based on the AA data yields the same result. These measurements indicate that the feldspar in the -18 + 35 mesh fraction of till in the Cuba Moraine contains approximately 25% more K-feldspar than the feldspar in the -120 + 250 mesh fraction.

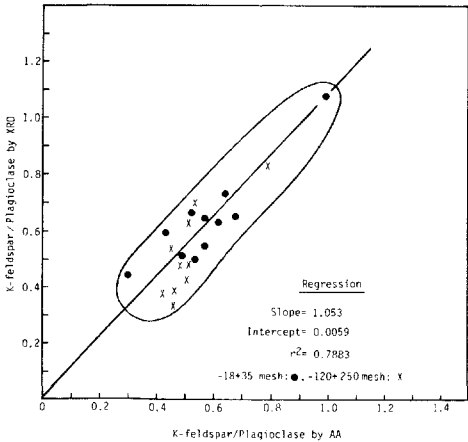


FIGURE 2. Correlation of K-feldspar-plagioclase ratios of till from the Cuba Moraine determined by X-ray diffraction (XRD) and atomic absorption (AA).

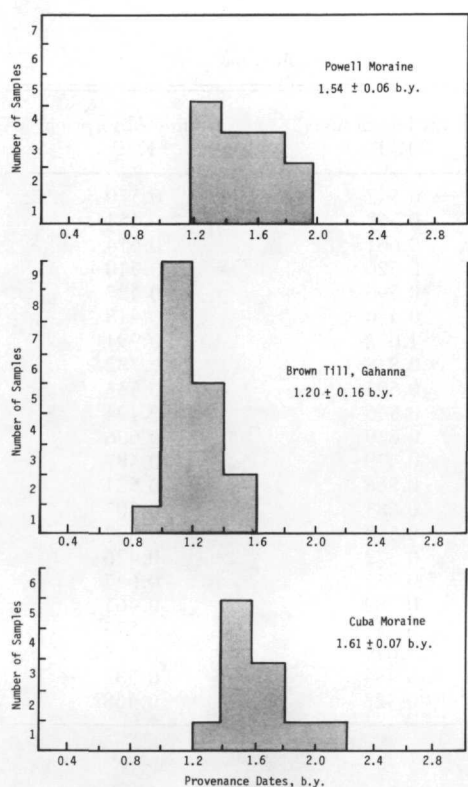


FIGURE 3. Histograms of Rb-Sr provenance dates of feldspar from the Cuba and Powell Moraines and from Gahanna.

The apparent enrichment of the coarse fraction in K-feldspar and the complementary enrichment of plagioclase in the fine fraction confirms observations recorded previously by Dreimanis and Vagners (1971), Haldorsen (1977, 1978), Taylor and Faure (1981) and Faure and Taylor (1981a).

Additional studies of till from southwestern Ontario and northern Ohio are in progress and will be used to test the hypothesis that the observed mineralogical fractionation of feldspar in till is related to the distance of transport.

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